

The willingness to vaccinate increases when vaccination protects others who have low responsibility for not being vaccinated

Robert Böhm¹  · Nicolas W. Meier¹ · Marina Groß¹ · Lars Korn^{2,3} · Cornelia Betsch^{2,3}

Received: July 30, 2018 / Accepted: October 25, 2018 / Published online: November 1, 2018
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Abstract Vaccination provides direct protection for the vaccinating individual and indirect protection for other, unvaccinated individuals via herd immunity. Still, some people do not get vaccinated—either because they cannot (e.g., due to health conditions) or they don't want to (e.g., due to vaccine hesitancy). We investigate whether non-vaccinators' level of responsibility for not being vaccinated affects individuals' motivation to vaccinate and, thus, to indirectly protect non-vaccinators. In Study 1 ($N = 101$), the intention to vaccinate increased (Cohen's $d = 0.99$) when non-vaccinators were described as willing but unable to get vaccinated (low responsibility) compared to when they were able but unwilling to get vaccinated (high responsibility). Study 2 ($N = 297$) replicated this finding with regard to vaccination behavior in an interactive vaccination (I-Vax) game ($OR = 2.38$). Additionally, knowing about non-vaccinators' low responsibility also increased the willingness to vaccinate compared to when there was no information on non-vaccinators' level of responsibility. Amplified levels of social welfare concerns in the case of non-vaccinators' low responsibility mediated the latter effect. This finding informs effective communication strategies for improving the vaccination rates.

Keywords Vaccination · Prosociality · Attribution theory · Herd immunity

Introduction

Besides directly protecting the vaccinated individuals, most vaccines also provide indirect protection for unvaccinated individuals, a phenomenon which is often referred to as 'herd immunity' (Fine et al., 2011). Herd immunity results from the reduced spreading of a pathogen due to an increasing vaccination rate in the population. At a certain vaccination rate, a disease can eventually be eliminated, as has happened in the case of smallpox (Breman & Arita, 1980). Hence, herd immunity is key for reaching public health goals of disease eradication and elimination (WHO, 2013). Importantly, herd immunity protects individuals who are not able to vaccinate because they are, for instance, too young to get vaccinated or immunocompromised (e.g., Rubin et al., 2014). These groups depend on indirect protection through others. In the US, for instance, between 0.26 and 0.41% of the children were not vaccinated on medical grounds during the period of 2004–2011 (Stadlin et al., 2012).

Due to the positive externalities to unvaccinated others, vaccination can be conceptualized as a prosocial act (e.g., Bauch & Earn, 2004; Betsch et al., 2013). Accordingly, given that individuals (1) know of the positive social consequences of vaccination stemming from herd immunity and (2) care about the welfare of others, they should be more willing to bear the personal costs of vaccination (e.g., effort, time, risk of vaccine side effects). Supporting this perspective, there is experimental evidence that prosocial motives are related to vaccine uptake (Böhm et al., 2016b). Moreover, making the prosocial aspects of vaccination

✉ Robert Böhm
robert.boehm@rwth-aachen.de

¹ School of Business and Economics, RWTH Aachen University, Templergraben 64, 52062 Aachen, Germany

² Media and Communication Science, University of Erfurt, Nordhäuser Str. 63, 99089 Erfurt, Germany

³ Center for Empirical Research in Economics and Behavioral Sciences, University of Erfurt, Nordhäuser Str. 63, 99089 Erfurt, Germany

salient fosters vaccine uptake, e.g., informing individuals about the social benefit of herd immunity has been shown to increase vaccination intentions, particularly when the subjective costs of vaccination are low (Betsch et al., 2013; 2017; Vietri et al., 2012).

Identifying moderators that increase individuals' willingness to vaccinate in order to protect others, appears promising for increasing the vaccination rates. Previous research has merely focused on characteristics of the vaccinating individuals. For instance, stable interpersonal differences in the general prosocial orientation predicted differences in vaccine uptake (Böhm et al., 2016a). Less is known about how assumptions about others' level of responsibility for not being vaccinated influences an individual's own willingness to get vaccinated. As noted above, there are people who are *willing* to get vaccinated but *unable* to do so. However, there are also individuals who are *able* but *unwilling* to vaccinate. Although the majority could get vaccinated, vaccine hesitancy stops some from doing so (MacDonald & SAGE Working Group on Vaccine Hesitancy, 2015). Vaccine hesitancy can be the result of *complacency*, i.e., low perceived risk of vaccine-preventable diseases, *constraints*, i.e., subjective and/or objective barriers, low *confidence*, i.e., lack of trust in the safety of vaccines and/or the health system, or *calculation*, i.e., cost–benefit analyses. Additionally, free-riding on others' indirect protection and negating one's *collective responsibility* also contribute to vaccine hesitancy (e.g., Betsch et al., 2015; 2018).

In the present contribution, we ask whether knowing that unvaccinated others cannot or do not want to get vaccinated, i.e., their personal level of responsibility, influences individuals' willingness to vaccinate. Beyond scientific interest, this question also has practical implications for how to communicate the social benefits of herd immunity. Given that information materials communicate the social benefits of herd immunity at all, they often emphasize that some others are unable to get vaccinated (e.g., CDC, 2017; ECDC, 2015). However, although this appears to be common practice, there exists no empirical evidence on whether communicating that unvaccinated others have a low responsibility for being unvaccinated has any effect at all compared to when there is no information on others' level of responsibility. Therefore, we conducted two experiments with about 400 participants overall to systematically investigate the impact of non-vaccinators' level of responsibility for not being vaccinated on others' motivation to get vaccinated. Before we present our experimental studies, we will analyze theoretically why non-vaccinators' level of responsibility should matter for others' willingness to get vaccinated and, in turn, to provide indirect protection for non-vaccinators.

The impact of non-vaccinators' level of responsibility for not being vaccinated

Decision makers are typically responsible for their decisions. Hence, leaving decision errors aside, a decision is a clear indicator of an individual's intention. As a consequence, 'good-doers' are rewarded and 'bad-doers' are punished in social interactions (e.g., Fehr & Gächter, 2002; Sigmund et al., 2001; for a meta-analysis, see Balliet et al., 2011). In the context of vaccination, however, some individuals cannot get vaccinated for medical reasons. Herd immunity is particularly important for protecting these individuals. Note that from the perspective of individuals who can freely decide whether to vaccinate or not, the consequences are identical, i.e., unvaccinated individuals will benefit from indirect protection, irrespective of whether these persons have high responsibility for not being vaccinated (i.e., able but unwilling) or not (i.e., willing but unable to vaccinate).

Based on attribution theory, humans perceive, interpret and react differently to others' behaviors depending on a number of causal dimensions (Weiner, 1986). One of these dimensions is the controllability of behavior, which determines whether someone is perceived as being responsible for the consequences of his/her behavior (Weiner, 1993). For instance, Weiner and Kukla (1970) showed that knowledge of students' ability (e.g., intelligence) and motivation (e.g., learning effort) affected how participants evaluated these students' positive or negative results in an exam. When students had less control (low ability) but were highly motivated, their success was evaluated more positively and their failure was evaluated less negatively than when they were not motivated. Hence, students' responsibility for an outcome was important over and above the mere quality of the outcome, serving as an intensifier of reward or as a buffer against punishment. Other research has applied these insights to the health domain. For example, people like and help others who have illnesses-related stigmas more when they perceive a low personal responsibility due to a low controllability (e.g., Alzheimer's disease). The opposite is true when others are perceived as being responsible for their illness due to controllable misbehavior (e.g., drug addiction) (Weiner et al., 1988; see also Crandall & Biernat, 1990; Rodin et al., 1989).

Building on these insights, we argue that in the context of vaccination, non-vaccinators could be perceived as having a high level of responsibility (high controllability but low motivation) or low level of responsibility (low controllability but high motivation) for their vaccination status. Given that the motivation to protect others through one's own vaccination decision plays a role for individual decision makers (e.g., Betsch et al., 2017; 2018; Böhm

et al., 2016b), the non-vaccinators' level of responsibility should also affect the decision makers' perceived collective responsibility, i.e., their motivation to provide indirect protection via herd immunity (Betsch et al., 2018). Therefore, we hypothesize that the intention to get vaccinated is higher when unvaccinated others have low responsibility than when they have high responsibility for being unvaccinated. Study 1 aimed at providing an initial test for this hypothesis.

Study 1

Materials and methods

Participants and design

We applied a one-factorial within-subjects design. Participants were asked for their intention to get vaccinated both given that the unvaccinated others were willing but unable (*low responsibility* condition) versus able but unwilling to get vaccinated (*high responsibility* condition).

To determine the sample size, we assumed a small-to-medium-sized effect (Cohen's $d = 0.3$) in a t-test for dependent samples and a high statistical test power, i.e., $1 - \beta > .99$. Accordingly, participants were $N = 101$ individuals between 18 and 70 years of age ($M = 33.90$, $SD = 11.13$) from the US and UK, gathered via the online recruitment platform Prolific Academic (Peer et al., 2017).

Seventy-one participants were female. They received a fixed remuneration of £0.30 for completing the two-minute study.

Procedure

After giving informed consent, participants read some general information about a fictitious infectious disease and a respective vaccination against it with the possibility of some side effects. They learned that their own vaccination would also provide indirect protection for others because the latter would be less likely to become infected. Participants were informed that there are different reasons why others are not vaccinated, including babies and immunocompromised individuals as examples of individuals who have low responsibility for not being vaccinated. The reason why others are not vaccinated was also included in the respective question that asked for the intention to get vaccinated (both on the same screen, in a randomized order): 'Are you motivated to protect people, who do not want to get vaccinated and have a negative attitude towards vaccination, by getting vaccinated yourself?' (*high responsibility*) and 'Are you motivated to protect people, who are not able to get vaccinated and have a positive attitude towards vaccination, by getting vaccinated yourself?' (*low responsibility*; each on a 7-point scale 1 = *not at all* to 7 = *totally*). Finally, participants answered some basic demographic questions regarding their age, gender and whether they have children.

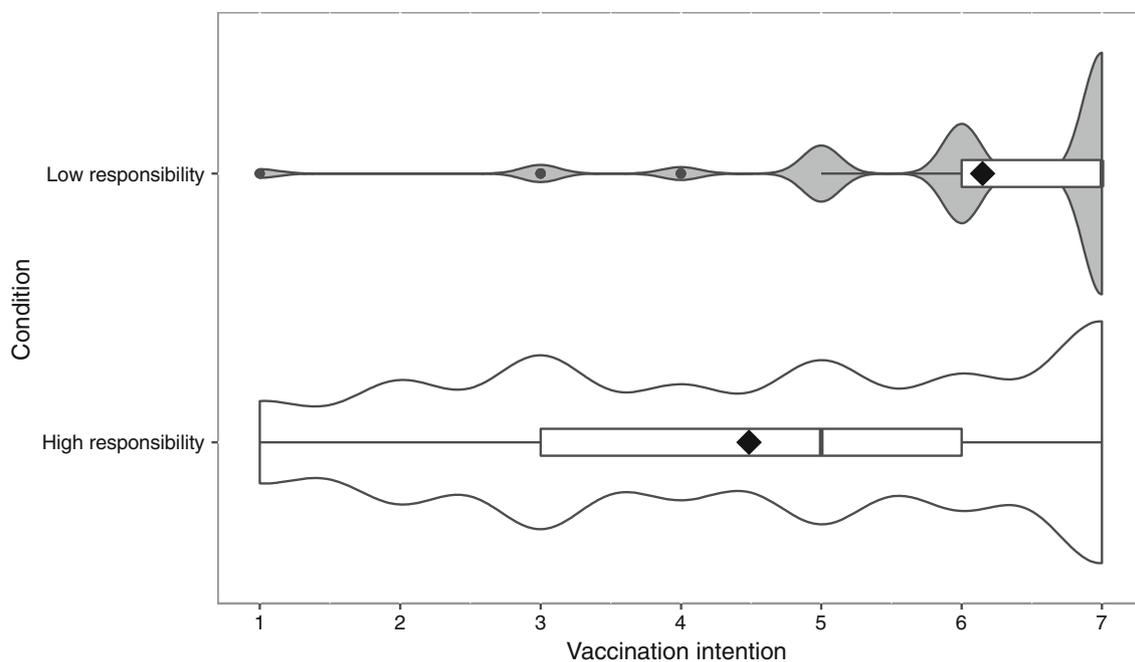


Fig. 1 Violin plot of vaccination intentions by within-subjects condition in Study 1 ($N = 101$). *Note.* Diamonds represent mean values, thick lines represent median values, the boxes represent the interquartile range, and the whiskers represent 1.5 times the interquartile range

Results

As shown in Fig. 1, the intention to get vaccinated in order to protect highly responsible non-vaccinators was almost uniformly spread over the whole scale ($Mdn = 5$, $M = 4.49$, $SD = 1.99$), whereas the willingness to protect others who have little responsibility for their non-vaccination was more left-skewed ($Mdn = 7$, $M = 6.15$, $SD = 1.28$). The difference between the conditions was significant, using both a t -test for dependent samples, $t(100) = -8.37$, $p < .001$, Cohen's $d = 0.99$, as well as when considering the non-normality of the distribution in a non-parametric Wilcoxon signed rank test, $Z = 6.52$, $p < .001$.

Discussion

Study 1 provides initial support for the assumption that non-vaccinators' level of responsibility for their lack of vaccination plays an important role in others' willingness to protect them indirectly through vaccination. Although we found a large effect size (Cohen, 1988), the result should be interpreted with caution.

A potential limitation is the artificial decision situation, which provided almost no context information (e.g., about risks of the disease and vaccine side effects). Moreover, the within-subjects manipulation potentially exaggerated the effect. Lastly, we provided the example of babies and immunocompromised individuals as persons who are not able to get vaccinated. However, there is evidence that the motivation to protect others is attenuated when the recipient is an identifiable young person (Li et al., 2016). Hence, the increased vaccination intention could at least partly be driven by higher prosociality towards babies, irrespective of their responsibility of not being vaccinated.

Therefore, Study 2 aimed to replicate the result in a more internally and externally valid experimental setting. We applied a between-subjects manipulation of the level of responsibility for not being vaccinated. We assessed the perceived level of responsibility of unvaccinated others with supplementary manipulation checks. Importantly, a control condition was added in which no information about the non-vaccinators' level of responsibility was provided. This control condition provides additional insights into how non-vaccinators' default level of responsibility is perceived. Moreover, we did not provide specific examples of people in the different conditions in order to exclude the potentially confounding effect of varying levels of prosocial motivation towards specific groups of beneficiaries.

Study 2

In the second study, we used the interactive vaccination game (I-Vax game; Böhm et al., 2016a) to measure vaccination behavior in a more realistic setting. The I-Vax game provides context information about risks from the disease and vaccine side effects, and it models both the direct and indirect effects of vaccinations, i.e., the social benefit of vaccination by protecting unvaccinated others (for details, see below). Therefore, the I-Vax game is an ideal tool for investigating vaccination behavior which also takes prosocial aspects into account. Importantly, within the game, individual decisions have actual consequences, i.e., the outcomes from infection with the disease or vaccine side effects are translated into monetary payoffs. Supporting the validity of the game paradigm, previous research has shown that individual decisions in the I-Vax game are related to the decision makers' vaccination attitude and prosocial orientation (Betsch & Böhm, 2016; Böhm et al., 2016a; 2017).

Following the explorative evidence from Study 1, we preregistered the hypothesis as well as the planned sample size and statistical analyses of Study 2. The preregistration can be accessed at <https://aspredicted.org/et85j.pdf>.¹ Accordingly, we expected a higher vaccination rate when decisions makers are informed that there are unvaccinated individuals who are less responsible compared to when they are informed that unvaccinated individuals are highly responsible for not being vaccinated. We explain how the experimental factors were operationalized in the I-Vax game below.

Materials and methods

Participants and design

We applied a one-factorial between-subjects design with three conditions (*high responsibility*, *low responsibility*, and *control*). The vaccination decision in the I-Vax game (yes vs. no) served as the main dependent variable. We expected a small-to-medium-sized effect in the difference between vaccination rates of the *high responsibility* versus *low responsibility* condition, which corresponds to an odds ratio of 2.33. This results in a minimum of $n = 95$ participants per condition (given that $\alpha = 0.05$ and $1 - \beta = 0.8$). We had an additional *control* condition, in which participants received no information about the level of responsibility of the unvaccinated participants. Although we did not preregister hypotheses regarding the vaccination rate in the

¹ In the preregistration form, 'intentional non-vaccination' refers to the *high responsibility* condition and 'unintentional non-vaccination' refers to the *low responsibility* condition.

control condition compared to the other conditions, it was conducted in order to explore how the willingness to vaccinate in the two conditions with explicit information about non-vaccinators' level of responsibility relates to a situation where no such information is given.

Accordingly, we sampled 303 participants. Based on preregistered criteria, we excluded 6 participants due to a study completion time of less than 3 or more than 25 min, or because of an incorrect answer to an attention check item (Oppenheimer et al., 2009). The final sample therefore consists of $N = 297$ participants ($n = 99$ in *high responsibility*, $n = 100$ in *low responsibility*, and $n = 98$ in *control*).

Vaccination intention and vaccination decision

Participants were endowed with 100 fitness points, which represent their health status in the I-Vax game (Böhm et al., 2016a). Fitness points convert into money at a conversion rate of 100 fitness points = £0.5. Participants learned that they would be part of a group of about 125 participants and that there was a fictitious disease threatening their health. Vaccination could protect them from infection. Vaccination yields fixed costs (10 fitness points), modeling effort, time, or fear of the needle prick. With a probability of 48%, there are additional costs due to side effects, reducing the health status by a further 35 fitness points. Taken together, the expected costs from vaccination are 26.8 fitness points (see Fig. 2, dashed line).

For unvaccinated participants, there is a risk of infection. Infection with the disease costs 50 fitness points. The probability of infection depends on how many participants

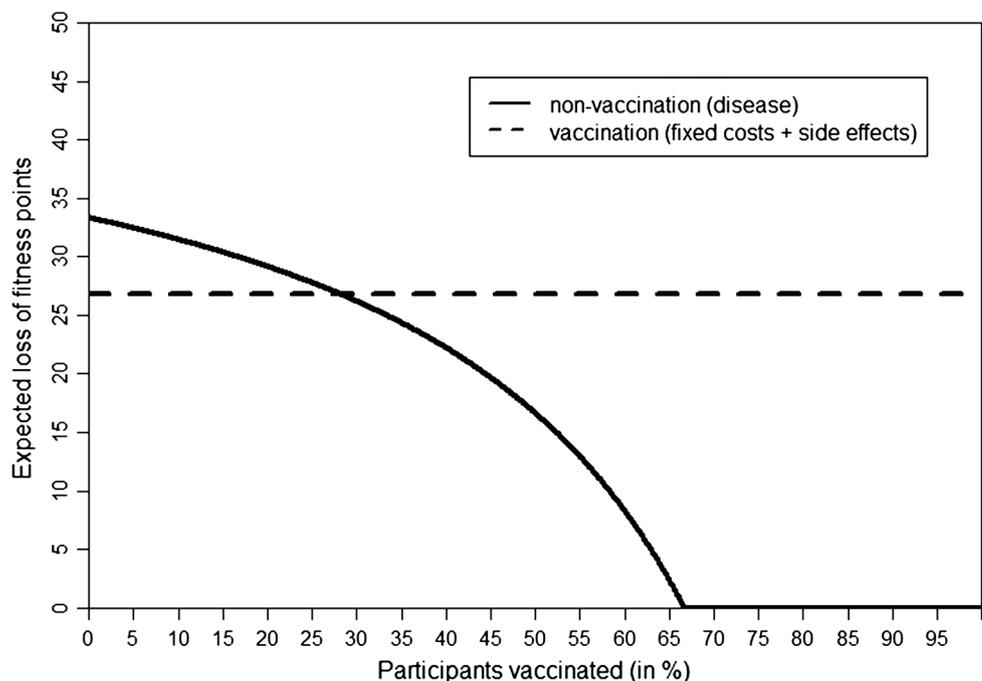
in the group are vaccinated. Modeling herd immunity (Fine et al., 2011), the probability of infection decreases with an increasing vaccination rate. As a consequence, the expected costs of non-vaccination decrease with the number of others vaccinated (see Fig. 2, solid line; this corresponds to a disease with a basic reproduction number $R_0 = 3$, for details regarding the epidemiological modeling, see Böhm et al., 2016a). For instance, there is an expected loss of 33.2 fitness points when no one gets vaccinated. If at least 67% of the group members get vaccinated, the disease will be eliminated and participants who are not vaccinated cannot get infected, yielding an expected loss of zero fitness points.

The vaccination decision was a one-shot binary choice. Before participants stated their vaccination intention on a continuous scale from 0 to 100 to have an additional, more sensitive measure for capturing potential motivational differences.

Experimental conditions

Across all conditions, participants learned that 25 people, i.e., about 20% of the population, would definitely not get vaccinated. Given a population size of 125 individuals, a fixed number of 25 non-vaccinators requires a vaccination rate of 84% among the remaining participants (i.e., 84 of 100 individuals) in order to reach an overall vaccination rate of $84/125 = 67\%$, which suffices to eliminate the disease and, therefore, to effectively protect also the non-vaccinators from infection with the disease.

Fig. 2 Expected loss of fitness points (y-axis) in the case of non-vaccination (due to potential infection with the disease; solid line) and in the case of vaccination (due to fixed costs and potential side effects; dashed line) by the relative number of participants vaccinated (x-axis)



We varied the information on whether these people are responsible for not being vaccinated. In the *high responsibility* condition, participants read: ‘These participants have a negative attitude towards vaccination and do not want to get vaccinated.’ In the *low responsibility* condition, it was stated: ‘These participants have a positive attitude towards vaccination but are unable to get vaccinated.’ Finally, in the *control* condition, participants received no additional information.

Additional measures

Manipulation checks We had two manipulation checks. First, we measured participants’ perceived behavioral control (Ajzen, 2002) of the unvaccinated participants with four 7-point Likert-type scale items (e.g., ‘For the 20% of participants who will definitely not get vaccinated, vaccination would have been possible.’, 1 = *fully disagree* to 7 = *fully agree*; Cronbach’s $\alpha = .89$). Second, we measured the perceived vaccination attitude of the unvaccinated participants with three 7-point Likert-type scale items (e.g., ‘The 20% of participants who will definitely not get vaccinated think that it is a good idea to get vaccinated.’, 1 = *fully disagree* to 7 = *fully agree*; Cronbach’s $\alpha = .90$; adapted from Askelson et al., 2010). For the analyses, we used the participants’ mean value on each scale (behavioral control: $M = 4.91$, $SD = 1.76$; perceived vaccination attitude of unvaccinated participants: $M = 3.42$, $SD = 1.86$).

Behavioral motivations We additionally asked participants to state the importance of egoistic, altruistic, and social welfare concerns as a reason for their vaccination decision. Each motivation was assessed with one 7-point Likert-type scale item; egoism: ‘My own maximization of fitness points played an important role in my decision.’, altruism: ‘The maximization of fitness points of the 20% of participants who will definitely not get vaccinated, played an important role in my decision.’, social welfare concerns: ‘The maximization of fitness points of the whole group including myself played an important role in my decision.’ (1 = *fully disagree* to 7 = *fully agree*).

Prosocial orientation Moreover, we used the Social Value Orientation (SVO) slider measure (Murphy et al., 2011) to assess participants’ general prosocial orientation. The measure consists of six dictator-game-like allocation decisions, in which participants have to allocate monetary points between themselves (sender) and an unknown other person (recipient). All participants made decisions in the role of the sender. For their payment, their role was

determined randomly. Allocation decisions in favor of oneself reflect selfish or negative other-regarding preferences (i.e., competitiveness), while distributing more points to the recipient indicates positive other-regarding preferences (i.e., fairness, altruism and/or social welfare concerns). All six items result in a single angle-index of a participant’s prosocial orientation, ranging between -16.26° and 61.39° , which is used for the analyses. Higher values indicate higher prosociality. One of the six allocation decisions was payoff-relevant for the sender and a matched recipient, with a conversion rate of 100 points = £0.50. On average, participants had rather positive other-regarding preferences ($M = 29.04^\circ$, $SD = 13.55^\circ$).

General vaccination attitude Finally, participants’ own attitude towards vaccination was measured with three 7-point Likert-type scale items (e.g., ‘It is a good idea to get vaccinated.’, 1 = *fully disagree* to 7 = *fully agree*; Cronbach’s $\alpha = .94$; Askelson et al., 2010). For the analysis, we used the mean value of the scale ($M = 6.15$, $SD = 1.29$).

Procedure

For this online study, participants were recruited via Prolific Academic (Peer et al., 2017). Each participant provided informed consent at the beginning of the study and agreed that his/her anonymized data could be used and published for scientific purposes. First, participants completed the SVO slider measure, followed by the measure of their general vaccination attitude.

Afterwards, the I-Vax game was described, including information about the probabilities and potential outcomes of the behavioral options, i.e., fixed costs and possible side effects in the case of vaccination, possible infection with the disease in the case of non-vaccination, as described above. Participants learned about the direct and indirect effects (through to herd immunity) of vaccination, e.g., they were shown Fig. 2 along with a verbal description. An attention check followed. In the case of a correct answer, participants were allocated randomly to one of the three experimental conditions. Participants completed the manipulation checks, followed by the assessment of their vaccination intention and actual vaccination decision. Finally, they answered questions about their behavioral motivation and demographics (age, gender).

For completion of the study, which had an average completion time of 8 min, all participants received a fixed remuneration of £0.80. Moreover, participants received a decision-contingent bonus payment based on the payoffs of the SVO slider measure and the I-Vax game (up to £1). Payments were executed via Prolific Academic.

Note that the predetermined unvaccinated participants were not part of the main study. These participants were assessed in a separate study using Prolific Academic, which was conducted after the main study. They received a fixed remuneration and an additional bonus payment according to the infection probability that resulted from the vaccination rate in the main study. Thus, participants in the main study were not deceived but their vaccination decision did indeed protect others who were not able to vaccinate themselves in the I-Vax game. In detail, we assessed these participants' general attitudes towards vaccination using a 6-point item ('In general, ... [I am against vaccinations] to [fully support vaccinations]'). Participants were classified as having either a positive or a negative vaccination attitude based on a predefined cut-off value (i.e., a value below vs. above the midpoint of the scale). Individuals with a negative vaccination attitude were then asked whether they wanted to participate in the study as an unvaccinated, passive participant. These individuals served as unvaccinated participants in the *high responsibility* condition. Individuals with a positive vaccination attitude were told that they cannot get vaccinated, and they served as unvaccinated participants in the *low responsibility* condition. Thus, the information about non-vaccinators provided to participants in the main study was correct, in the sense that people in the *high responsibility* condition were able (but opted against it) and not willing (by having a low vaccination attitude), whereas people in the *low responsibility* condition were willing (by having a high vaccination attitude) but unable to get vaccinated. Individuals who served as unvaccinated participants in the control condition had no predefined vaccination attitude.

Data analysis

First, we analyze the effectiveness of the experimental manipulation by looking at the manipulation checks. Second, we report the result of the preregistered hypothesis. Finally, we conduct additional explorative analyses without preregistered hypotheses.

We report two-sided p values for all tests. Moreover, we also report effect size estimates along with significance tests and 95% bootstrapped confidence intervals (applying 10,000 iterations) when reporting mediation analyses in order to further explore the underlying motivational processes. The continuous vaccination attitude is $\log(10)$ -transformed for all analyses to account for the skewed distribution. Moreover, we apply analyses of variance (ANOVAs), which are robust regarding violations of normal distribution.

Results

Manipulation checks

Perceived behavioral control of others to get vaccinated was $M = 5.56$ ($SD = 1.40$) in the *control condition*, $M = 5.66$ ($SD = 1.13$) in the *high responsibility* condition, and $M = 3.52$ ($SD = 1.77$) in the *low responsibility* condition. As intended, there was a significant difference between conditions, $F(2, 294) = 68.08$, $p < .001$, $\eta_p^2 = .32$. Bonferroni-corrected post hoc tests revealed higher perceived behavioral control in the *high responsibility* condition versus *low responsibility* condition ($p < .001$), as well as higher behavioral control in the *control* condition versus *low responsibility* condition ($p < .001$). The *high responsibility* condition did not differ from the *control* condition ($p = 1.00$).

Others' perceived vaccination attitude received an average rating of $M = 2.68$ ($SD = 1.35$) in the *control condition*, $M = 2.43$ ($SD = 1.33$) in the *high responsibility* condition, and $M = 5.11$ ($SD = 1.53$) in the *low responsibility* condition. As intended, there was a significant difference between conditions, $F(2, 294) = 110.46$, $p < .001$, $\eta_p^2 = .43$. Bonferroni-corrected post hoc tests revealed that the perceived attitude of unvaccinated others was more positive when these individuals had low versus high responsibility for not being vaccinated ($p < .001$), as well as when participants had low responsibility versus when there was no reason given in the control condition ($p < .001$). There was no difference between the *high responsibility* condition and the *control* condition ($p = .627$).

Thus, unvaccinated others in the *low responsibility* condition were perceived as being more willing (higher attributed vaccination attitude) but less able (lower attributed behavioral control) to get vaccinated than unvaccinated individuals in the *high responsibility* condition as well as in the *control* condition. As such, the manipulation proved to be successful.

Vaccination intention and behavior

Participants' mean vaccination intention was $M = 87.62$ ($SD = 22.90$) in the *low responsibility* condition, $M = 79.70$ ($SD = 32.10$) in the *high responsibility* condition, and $M = 80.02$ ($SD = 29.69$) in the *control* condition (for distributions, see Fig. 3). This corresponds to their actual vaccination behavior: In the *low responsibility* condition, 92% of the participants decided to get vaccinated. In the *high responsibility* and *control* conditions, 82% and 80% of the participants got vaccinated, respectively. Given the parameterization of the I-Vax game as

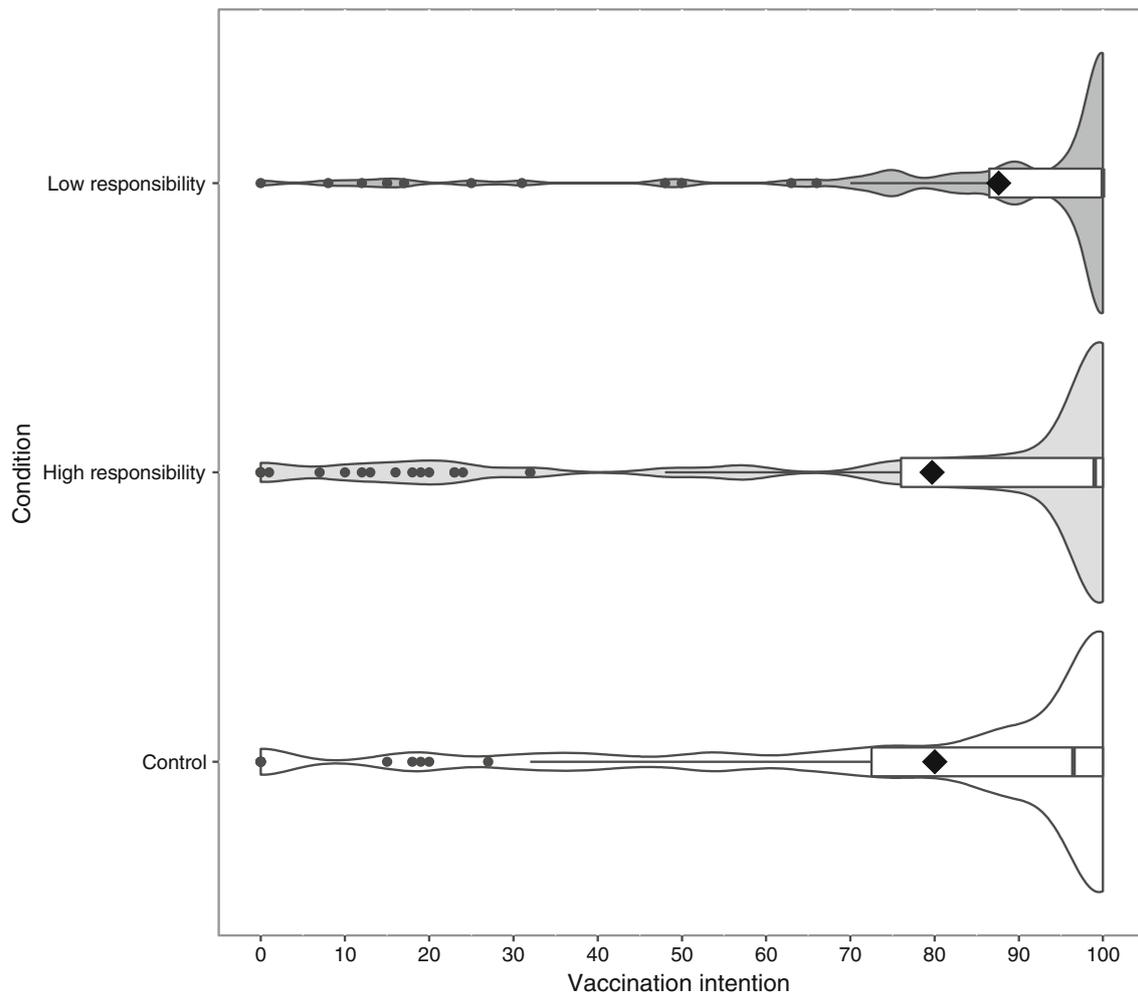


Fig. 3 Violin plot of vaccination intentions by between-subjects condition in Study 2 ($n = 100$ in low responsibility, $n = 99$ in high responsibility, $n = 98$ in control). *Note.* Diamonds represent mean

values, thick lines represent median values, the boxes represent the interquartile range, and the whiskers represent 1.5 times the interquartile range

described above, the critical vaccination rate of 84% to effectively protect unvaccinated individuals from infection by eliminating spreading of the disease was reached only in the *low responsibility* condition but not in the *high responsibility* and *control* conditions.

We expected the vaccination rate to be higher when unvaccinated others are less responsible for being unvaccinated compared to when they are more responsible. We tested this preregistered hypothesis in a logistic regression analysis, predicting individuals' vaccination decision (0 = non-vaccination, 1 = vaccination) by condition (*high responsibility* vs. *low responsibility* condition). As hypothesized, participants were about 2.4 times more likely to get vaccinated when unvaccinated participants were less responsible than when they were more responsible for not being vaccinated, $B = 0.87$, $SE = 0.46$, $p = .056$, odds ratio (OR) = 2.38, 95% CI [.98, 5.81]. This result replicated when predicting participants' continuous vaccination

intention (log-transformed) in a one-way ANOVA, $F(1, 197) = 4.17$, $p = .042$, $\eta_p^2 = .02$.

As an additional explorative analysis, we controlled for individuals' vaccination attitude and prosocial orientation when predicting the dichotomous vaccination decision by condition. We found that the effect of condition decreased slightly, $B = 0.71$, $SE = 0.54$, $p = .193$, $OR = 2.03$, 95% CI [.70, 5.89]. In addition, vaccination attitude, $B = 1.04$, $SE = 0.19$, $p < .001$, $OR = 2.83$, 95% CI [1.95, 4.10], and to a lesser degree prosocial orientation, $B = 0.03$, $SE = 0.02$, $p = .112$, $OR = 1.03$, 95% CI [.99, 1.07], predicted vaccine uptake. These results are comparable to previous studies using the I-Vax game (e.g., Böhm et al., 2016a; 2017) and therefore provide further support for the game's reliability and external validity in modeling vaccination behavior. Note that there are no significant interaction effects between vaccination attitude or prosocial orientation and condition.

We further explored the differences in vaccination behaviors relative to the *control* condition, in which participants received no specific information about why others had decided against vaccination. In a logistic regression analysis predicting vaccination behavior by condition, vaccination uptake in the *low responsibility* condition was significantly higher than in the *control* condition, $B = 0.95$, $SE = 0.45$, $p = .035$, $OR = 2.59$, 95% CI [1.07, 6.27]. Vaccine uptake in the *high responsibility* condition did not significantly differ from the *control* condition, $B = 0.08$, $SE = 0.37$, $p = .826$, $OR = 1.09$, 95% CI [.52, 2.25]. This means, vaccine uptake increased when people knew that unvaccinated others were unable (but willing) to get vaccinated compared to the ‘default’ situation, where people had no information about others’ level of responsibility for not being vaccinated.

Mediation analysis

In order to better understand the latter effect, we explored the potentially underlying (change in) behavioral motivations, i.e., maximization of the own welfare (egoistic concerns), maximization of non-vaccinators’ welfare (altruistic concerns), and maximization of the vaccinators and non-vaccinators’ welfare (social welfare concerns), each assessed with a single item directly after the vaccination decision.

We conducted a multiple mediation analysis (Hayes, 2013). We used the continuous vaccination intention (log-transformed) as a dependent variable due to its higher resolution (and therefore, the increased test power). The results revealed that increased social welfare concerns serve as the sole mediator variable for the difference in vaccination intention between the *control* condition and the *low responsibility* condition, 95% CI of indirect effect [.001, 0.27], whereas (decreased) egoistic concerns, 95% CI [-.004, .013], and (increased) altruistic concerns, 95% CI [-.004, .014], were no significant mediator variables. In detail, the motivation to maximize the joint welfare of both vaccinated and unvaccinated individuals was higher when unvaccinated players were unable to get vaccinated (*low responsibility*) compared to when there was no information on their level of responsibility available (*control*), $B = 0.31$, $SE = 0.14$, $p = .032$. Social welfare concerns (while controlling for condition and the other behavioral motivations), in turn, predicted participants’ vaccination intentions, $B = 0.04$, $SE = 0.02$, $p = .021$.

Discussion

The results confirmed our hypothesis and therefore supported the initial finding from Study 1: Individuals were

more willing to get vaccinated when they were informed that vaccination would protect unvaccinated others who have low responsibility for not being vaccinated. This holds when compared to both the condition where unvaccinated individuals had high responsibility for their decision as well as in comparison with the condition where participants had no information about why people did not vaccinate. A further process analysis revealed that knowing that others are willing but unable to get vaccinated increased social welfare concerns, which then led to a higher vaccination intention. The theoretical and practical implications of these findings are discussed below.

General discussion

We tested the effect of non-vaccinators’ level of responsibility for not being vaccinated on others’ willingness to get vaccinated, and with this, to provide indirect protection for these unvaccinated individuals. Building on an attributional perspective of helping behavior (Weiner, 1986), we expected vaccination to become more likely when the resulting herd immunity protects unvaccinated others who are less responsible (vs. more responsible) for not being vaccinated. Our results support this hypothesis both in terms of vaccination intentions (Studies 1 and 2) as well as with regard to incentivized vaccination behavior in an interactive vaccination game (Study 2). Moreover, supporting the idea that vaccination is—at least partly—a prosocial act towards others, we provide additional evidence that the increased vaccination intention is due to a greater concern for social welfare.

Interestingly, the vaccination intention and behavior in response to intentional and therefore responsible non-vaccinators were very similar to the situation where individuals had no information about non-vaccinators’ level of responsibility. This suggests that people assume that others are typically responsible for their vaccination decision, which is not surprising given that only a small minority of people cannot get vaccinated for medical reasons. From a practical perspective, when communicating the social benefits of herd immunity (e.g., Betsch et al., 2017), it should be combined with additional information that (some) people are unable to get vaccinated and therefore are forced to rely on indirect protection through others’ vaccinations. Since this information is already provided in some information materials (e.g., CDC, 2017; ECDC, 2015; WHO, 2017), our findings provide the first empirical evidence that this is indeed likely to support vaccination intentions.

Limitations and outlook

Although the current studies provide evidence for the proposed hypothesis, they have some limitations to be addressed by future research. Firstly, Study 2 relies on incentivized vaccination behavior in an interactive vaccination game that incorporates the interplay of epidemiological, psychological, and economic aspects of vaccination decisions (see Böhm et al., 2016a). Clearly, our results rely on a specific set of parameters used in the interactive vaccination game, mirroring a low-severity disease and an effective vaccine. Future research should test the generalizability of the obtained effects in settings where the disease is more severe and where the vaccine is not perfectly effective. Moreover, although the game setting mirrors reality, it is still based on artificial vaccination decisions. Relatedly, we used convenience (online) samples and have little information about participants' characteristics (however, the online platform used has been shown to produce high-quality response data; Peer et al., 2017). Therefore, future research should replicate the findings using randomized controlled trials with regard to specific vaccines in selected target populations (e.g., parents who decide about their children's vaccination status), investigating actual vaccination behavior.

Secondly, and related to the former point, the participants of Study 2 had a very positive average attitude towards vaccination. Only for 6% (19 out of 297) of the participants was the vaccination attitude below the mid-point of the scale. Although there was no interaction effect between experimental condition(s) and vaccination attitude, future studies should test whether the proposed effect also holds for participants with less positive vaccination attitudes.

Thirdly, we had a share of 20% of the population as (predetermined) non-vaccinators in Study 2. This is rather high, particularly with regard to the *low responsibility* condition. Realistically, we have to assume lower numbers of people who are not able to get vaccinated on medical grounds (Stadlin et al., 2012). Future research should therefore investigate whether the share of people who are unable to get vaccinated affects others' willingness to provide indirect protection.

Lastly, participants in our studies may have perceived that low responsibility for non-vaccination stemmed from medical reasons, either explicitly due to specific examples in Study 1, or implicitly in Study 2. However, there are also non-medical reasons for the decision against vaccination. For instance, exemptions from mandatory vaccinations on philosophical or religious grounds have increased in recent years (Omer et al., 2012). It would be interesting to investigate whether such non-medical exemptions result in a similarly increased willingness to vaccinate prosocially.

Based on our theorizing, we would expect a decrease in the willingness to protect unvaccinated individuals with increased perceptions of others' controllability over the factors that lead to non-vaccination. For instance, we would hypothesize that medical reasons are perceived as being less controllable than religious reasons. Moreover, this effect might be moderated by the participants' own attitudes towards the 'target group' (e.g., a religious group), which could give rise to health-based intergroup discrimination.

Conclusion

Without having further information, people perceive non-vaccinators as being responsible for not being vaccinated. We show that communicating that some people are unable to get vaccinated increases the willingness of others to protect these people indirectly. Thus, we provide empirical evidence that information materials emphasizing the need to protect unvaccinated individuals who have low responsibility for not being vaccinated are likely to lead to higher vaccine uptake than information materials that do not emphasize the beneficiaries' lack of responsibility.

Funding This work was supported by the German Research Foundation (DFG) under Grants BO 4466/2-1 to RB and BE 3970/8-1 to CB.

Data availability The data presented in this article are publicly available and can be accessed at <https://osf.io/b56yh/>.

Compliance with ethical standards

Conflict of interest Robert Böhm, Nicolas W. Meier, Marina Groß, Lars Korn, and Cornelia Betsch declare that they have no conflicts of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the German Psychological Association (Deutsche Gesellschaft für Psychologie) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all patients for being included in the study.

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